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Section for Quantitative Sustainability Assessment

Life cycle assessment of nanoadsorbents at early stage technological development

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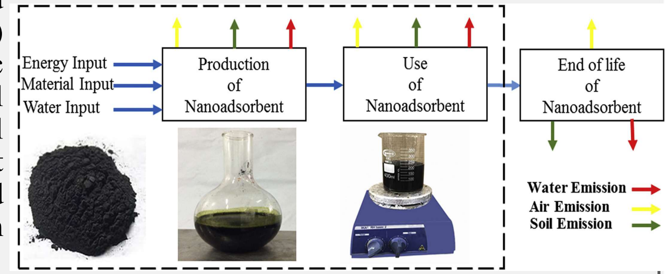
- Each technological development starts with an idea, and follows through Technological Readiness Levels (TRLs) from research and lab work and publication of scientific papers, over semi-industrial pilots, and finally, industrial development. Accordingly assessing the environmental impacts already during the initial stages of development can help identify potential trade-offs and possibly lead to development of more sustainable nanoadsorbents with fewer negative environmental impacts.

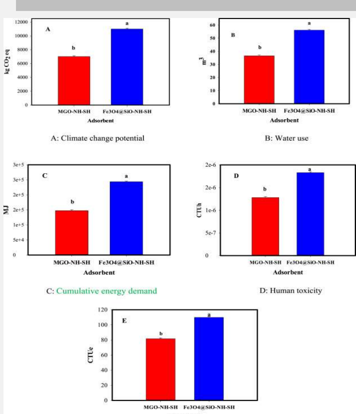


Recommendations for technology development

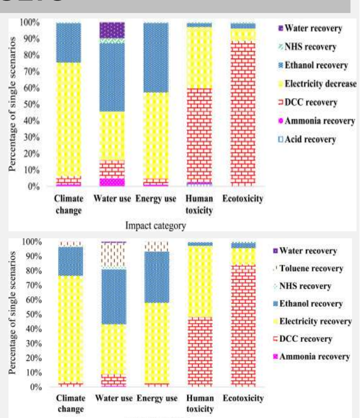
OBJECTIVES AND METHODS

- **LCA of nanoadsorbents as a special application of nanomaterials for the removal of pollutants from the environment.**
- **Goal:** To assess cradle-to-use life cycle impacts of thiol-functionalized magnetic graphene oxide, and superparamagnetic Fe3O4@SiO2, for application in water and wastewater treatment.
- **Functional unit:** 1 kg Hg removal from polluted water.
- **LCI:** Our laboratory experiments provided the process data for assessing cradle-to-use life cycle impacts of the produced adsorbents.
- **LCIA follows:**
  Water uses and climate change : ReCiPe midpoint method
  Cumulative Energy Demand (CED) method
  Human toxicity and ecotoxicity: USEtox
- **Sensitivity analyses: "What-if"**

RESULTS



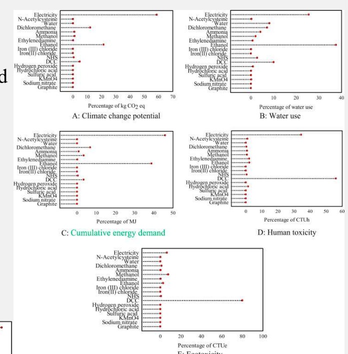
Comparison of studied impact categories for 1 kg Hg removal between MGO-NH-SH and Fe_3O_4@SiO-NH-SH; A: Climate change potential, B: Water use, C: Cumulative energy demand, D: Human toxicity, and E: Ecotoxicity.

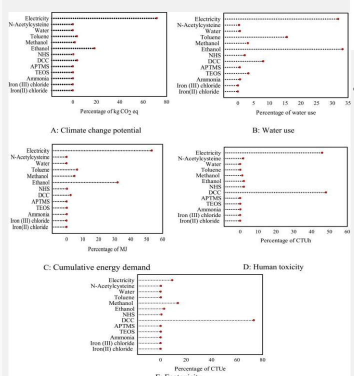


The results of the sensitivity analysis for MGO-NH-SH and Fe3O4@SiO-NH-SH. showing the importance of the single scenarios for the reduction of each impact category in percentage.

- **Which processes cause the most environmental impacts?**

- The main factors affecting climate change potential for MGO-NH-SH and Fe_3O_4@SiO-NH-SH:
  ⇒ Use of electricity for heating and cooling.
- Water use for both adsorbents:
  ⇒ the use of ethanol for washing during the production stage.
- The main contributor to human toxicity and ecotoxicity:
  ⇒ the use of DCC as a coupling reagent in the production stage.





The results of each impact category for MGO-NH-SH and Fe_3O_4@SiO-NH-SH based on 1 kg Hg removal

CONCLUSION AND PERSPECTIVES

Our results lead to a generalized finding, that the production of nanomaterials, particularly in specialized applications, e.g. nanoadsorbents, can be optimized through assessing the environmental impacts of their production and use at an early stage of technological development.
Sensitivity and uncertainty analysis showed the importance of recovering materials during production.

- **Further work needed** to:
  - To assess cradle-to-grade for nanoadsorbents.
  - Identify actual processes and specify data in semi-industrial pilots and industrial scale.
  - Work on exposure to nanoadsorbents during the whole life cycle

References: *Hadavifar et al., 2016; Arvidsson et al. (2014); Arvidsson et al., 2015 ; Healy et al. (2008); Huijbregts et al., 2006; M.A.J. Huijbregts et al., 2010; Kim and Fthenakis, 2013; Rosenbaum et al., 2008.*

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